Government of India
Ministry of Earth Sciences
Earth System Science Organisation

A knowledge and technology enterprise in the Earth System Science
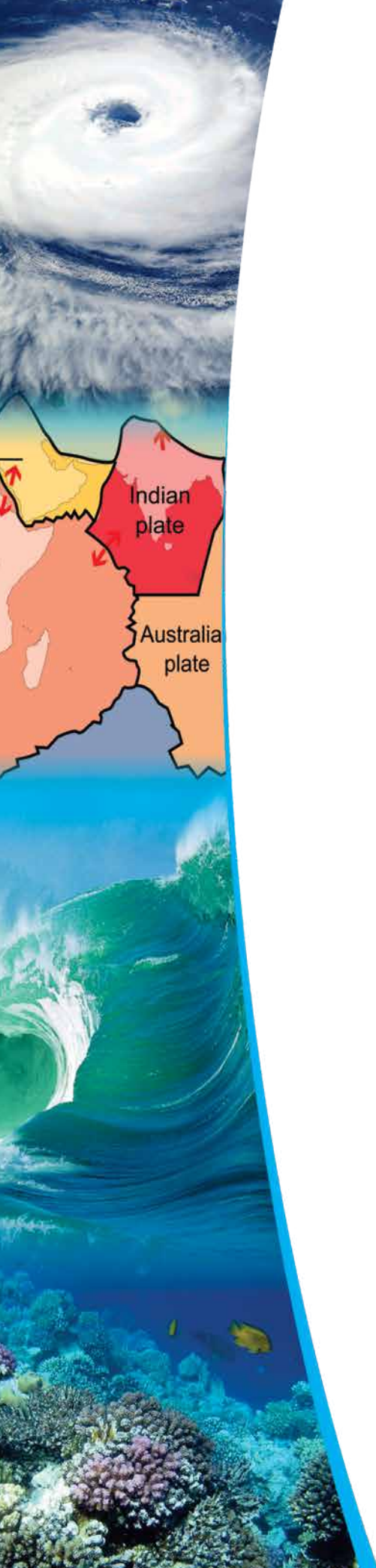for Public Safety and Socio-Economic Benefits to the Nation

VISION

for 2030

Government of India
Ministry of Earth Sciences
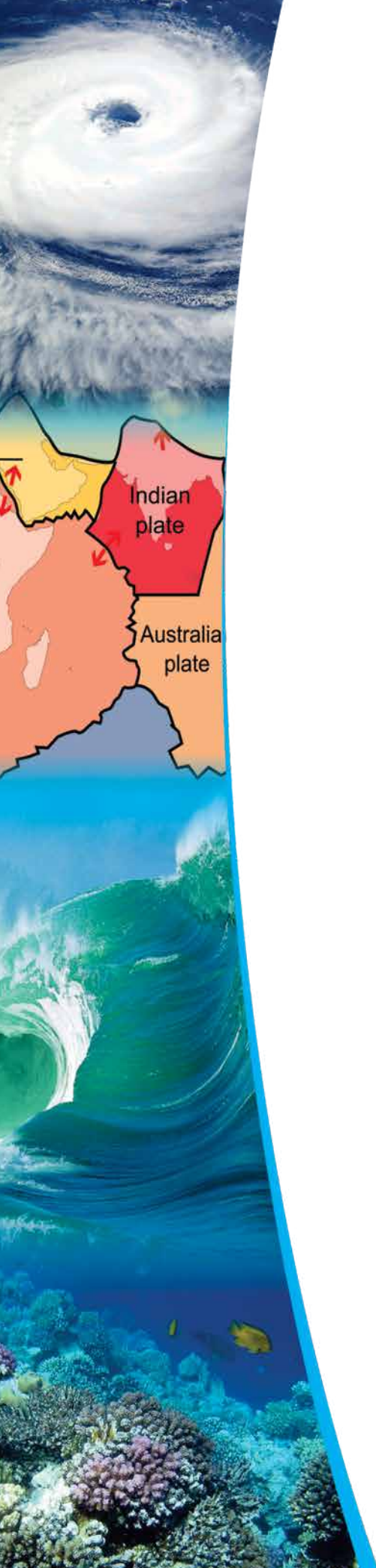Earth System Science Organisation

Vision
2030

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Indian
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Brief Account of Major Professional Accomplishments

Earth System Science Organization (ESSO), Ministry of Earth Sciences (MoES) is a knowledge enterprise in the Earth System Science for socio-economic benefits to the Nation. The Ministry of Earth Sciences was established in the year 2006 by bringing all the agencies of meteorological and ocean developmental activities under one umbrella. The sole purpose of the endeavour is to address holistically various aspects relating to earth system processes for improving forecast of the weather, climate and various natural geo-hazards. The ministry inter alia is responsible for development of technology towards the exploration and exploitation of marine resources in a sustainable way for the socio-economic benefits of the society. The mission of the Ministry is to provide services for weather, natural hazards, climate, ocean and coastal state, seismology, and exploring marine living and non-living resources and the polar regions. Over the past few years, the quality of weather, climate, ocean and seismological services provided by the ministry has been improved due to systematic efforts in augmenting atmospheric, coastal and ocean observations and survey, geophysical observations, polar research, developing adequate modelling strategy, conducting cutting edge research and investing in human resources development.
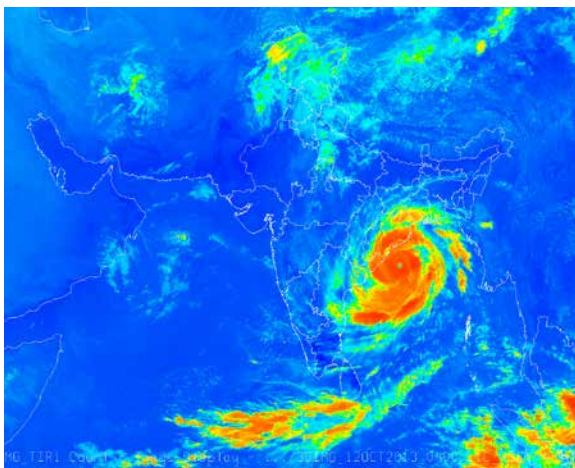
The major achievements made by the ministry during the past 10 years in general and 2 years in particular are illustrated below:

1) Weather and Climate Services

Quality of weather and climate services has improved over the last decade in general, and during the last two years in particular. This was possible due to augmentation of observational network, research efforts in weather and climate modelling and specialized training of scientists. Important achievements in weather and climate services are as follows:

- **Augmentation of atmospheric and climate observational network**
  - ➢ Augmentation of Doppler Weather Radar (DWR) Network from 4 in 2006 to 19 in 2016.
  - ➢ High quality upper air observational data network using the GPS technology has now been extended to 40 locations.
  - ➢ Augmentation of surface observational

Satellite Image of Tropical Cyclone Phailin

network by increasing the number of Automatic weather stations (AWS) from 125 to 675 and by introducing 1330 Automatic Rain-

gauges (ARG) leading to availability of meteorological observations from all the districts of the country.

➢ Better quality and high resolution digital data from INSAT-3D satellite and other satellites.

- **Development of dynamical prediction systems**

➢ Under the Monsoon Mission, dynamical prediction systems have been made operational based on the National Centers for Environmental Prediction (NCEP) Global Forecast System (GFS) and Climate Forecast System (CFS) models for short to medium range (up to 10 days), extended range (up to 20 days) and seasonal forecasts.

➢ The Unified Model (UM) based 4D-Variational Data Assimilation and Forecast System at 17 km (global) horizontal resolution has been made operational for short to medium range weather forecasts.

➢ A 1.5 km resolution nested regional model based on UM for experimental prediction of high impact weather systems

➢ Development of the Earth System model based on the CFS model with good fidelity in simulating the present climate and its variability. The first climate model from India to contribute to the forthcoming IPCC climate change assessment process.

➢ A 21-member Global Ensemble Forecasting System (GEFS) based on the GFS (22 km resolution) and a 44 member global ensemble prediction system (33 km horizontal resolution) based on UM for real time probabilistic predictions.

- **Quality of Services**

➢ Expansion of State level Agro-meteorological Advisory from 25 state units in 2006 to district level advisories through 130 Agromet Field Units (AMFUs) in 2009. By 2016 all 636 agricultural districts will be covered under these advisories.

➢ Presently around 1.91 Crores farmers are directly benefitted by this service being provided through SMS as compared to 0.5 Crores farmers in April 2014. In 2006, no such service was available. From the agro-meteorological advisories, farmers made economic benefits exceeding Rs. 42,000 crores.

➢ Noteworthy improvement in track and intensity forecast of the tropical cyclones (24 hour forecast error in track prediction reduced from 141 km to 97 km and Landfall error from 99 km to 56 km during 2006 to 2015). Accurate forecasts of recent cyclones, Phailin and Hud Hudh, thus saving human lives.

➢ Noticeable improvements achieved in skills of Heavy Rainfall Forecasts (False Alarm Rate reduced from 46% to 11% and Probability

of Detection increased from 49% to 67% from 2002 to 2015).

➢ Increase in validity of forecasts from 2 days in 2006 to 7 days in 2015 and spatial resolution from meteorological subdivision to district level. Block-wise forecasts for selected blocks have been introduced.

➢ Increase in city forecasts from around 30 in 2006 to 324 in 2016.

➢ Introduction of nowcasts of thunderstorms for 180 cities and highway and tourism forecasts.

➢ Improved the skill of seasonal forecasts of southwest monsoon season rainfall. Successful prediction of deficient monsoon rainfall in 2015. Introduction of seasonal forecasts for Northeast monsoon rainfall and Winter Precipitation.

➢ Quantitative precipitation forecast (QPF) to Central Water Commission (CWC) for flood warnings increased from 125 to 146 river sub-basins. Validity of QPF has been increased from 5 day to 7 days in 2015.

➢ Customised weather forecasts for each of Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES) member/ collaborating countries based on a 9-km regional model.

➢ Customised weather forecasts for Shri Amarnathji Yatra, Bhakra and Beas Management Board (BBMB), Indian Coastal Guard, Antarctica expeditions, and for wind energy applications.

➢ Establishment of the Centre for Climate Change Research at Indian Institute of Tropical Meteorology (IITM), Pune to conduct research on all aspects of the science of global and regional climate change.

➢ Generation of high resolution (35 km) of regional climate change scenarios (present and future climate) by using dynamical downscaling.

➢ Setting up Regional Climate Services at IMD Pune and introduction of Seasonal Climate Outlook for South Asia and monthly El Nino/ Southern Oscillation (ENSO) & Indian Ocean Dipole (IOD) Forecasts.

➢ Seasonal Outlook for Temperatures for the Hot Weather Season (April-June) was introduced in 2016.

➢ Specialized services for optimum operation of activities like irrigation, shipping, offshore oil explorations were augmented. Specialized services were introduced for Power & health sectors.

➢ Establishment of air pollution monitoring and forecasting network at Delhi, Mumbai and Pune. Development of a Mobile Application "SAFAR AIR" for knowing current air pollution levels on Mobile at three cities, Delhi, Mumbai and Pune.

- **Research and Development activities**

➢ Data assimilation research using advanced methods for improving

initial conditions of the atmosphere. Indigenously developed assimilation methods for the new Indian datasets (Oceansat-OSCAT, MT-SAPHIR, INSAT-3D Sounder, INSAT-3D AMV, DWR-VAD and MT-ROSA)

➢ Conducted research aircraft and surface based campaigns for understanding aerosol-cloud interactions over the polluted and non-polluted regions in India.

➢ Studies on monsoon variability on all time scales using models and observed data leading to improvement in predictions.

➢ Establishment of a state-of-the-art High Altitude Cloud Physics Observatory at Mahabaleshwar for aerosol and cloud observations.

➢ Establishment of a lightning network over Maharashtra for studying thunderstorm dynamics.

➢ Improvement of physical parameterization schemes for Cumulus Parameterization, Cloud Microphysics and Land Surface Processes in the CFS model. Process studies on aerosols, clouds, boundary layer and atmospheric chemistry.

2) Ocean Science Research and Services

Significant progress has been made in establishing a large ocean observing network for the Indian Ocean during the past 10 years. Systematic efforts were also made to develop high resolution ocean regional models with advanced data assimilation methods.

• Ocean Observational Data

➢ As of now, 19 moored buoys for providing continuous met-ocean data in real time since 2010. Additional 32 buoys were installed under the Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA) project.

➢ 28 Coastal ADCP moorings for the continuous measurements of coastal currents in the coastal waters of India and 10 HF Radars.

➢ Automatic Weather Stations on board 33 ships and 13 wave rider buoys along the Indian coast.

➢ 220 Argo profiling floats deployed since 2010 of which 134 are now active.

➢ 11 Current meter moorings in the equatorial Indian Ocean, 31 tide gauges and 7 Tsunami Buoys.

• Ocean Services and Research

➢ Routine forecasts of waves, tides and ocean general circulation parameters for various stakeholders on a daily basis. Estimated 3.5 lakh users accessing these forecasts daily.

➢ Generation of advisories on Potential Fisheries Zones (PFZ) based on satellite data on SST and Chlorophyll content in the sea water and dissemination through 558 fishing related centers. Estimated 2.75 lakh users made huge economic benefits.

➢ Establishment of the State-of-the-art Tsunami early warning system for the Indian Ocean Rim countries at INCOIS, Hyderabad. It has been designated as Regional Tsunami Service Provider (RTSP) by IOC/UNESCO entrusting the responsibility for providing tsunami advisories to Indian Ocean rim countries.

➢ Implementation of Storm Surge prediction system for the Indian coasts.

➢ Development of high resolution Ocean regional models with advanced ocean data assimilation system for ocean state forecasts.

➢ Development of state-of-the-art ocean data services for acquisition, archival and dissemination of the ocean data with linkages to many international Ocean data centers.

➢ Deployment of Ocean Data and Information Management System (ODIS) to receive and archive oceanographic and marine meteorological data in real time from different ocean observing systems.

➢ Systematic studies on biogeochemistry of the Indian Ocean using models and observations**.**

➢ Established a biodiversity information network-Ocean Biogeographic Information System (OBIS) consisting about 1.2 lakhs marine species diversity records from the Indian Ocean region. It has been recognized as regional node of international OBIS under the Intergovernmental Oceanographic Commission.

A Fisherman preparing for a fishing trip after looking at advisories on mobile

➢ Documented the dynamics of biogeochemical cycles through time series observations.

➢ Documented the seasonal variations on the emission of greenhouse gases viz. methane, nitrous oxide and carbon dioxide during upwelling season along the west coast of India

Tsunami Early Warning Centre

➢ Established the decadal changes in community composition of zooplankton (Secondary producers) in North and South Eastern Arabian Sea.

➢ Established a baseline database on the larval distribution and abundance of major commercially important coastal pelagic species such as oil sardine, anchovies and mackerel.

➢ Mapped the benthic biodiversity particularly abundance of polychaetes along the shelf of Andaman and Nicobar Archipelago.

➢ Documented centennial changes of harmful algal blooms and decadal changes in benthic biodiversity in the Arabian Sea.

➢ Establishment of Ornamental Fish culture at Agatti for economic benefit of Lakshadweep island families particularly women and children.

➢ Studies of causes of Coastal erosion and closure of tidal inlets at most vulnerable sites along the Indian coast and 16 site specific shoreline/ inlet management plans for coastal protection.

➢ Preparation of Tsunami Hazard Maps at 1:25000 scale based on collation of field data and numerical modelling for all possible Tsunami sources.

➢ Monitoring of coastal water quality (25 parameters) at 22 locations along Indian coast to assess the health of coastal waters.

3) Ocean and Atmospheric Technology

• Implementation of Low temperature thermal desalination technology in 3 islands of Lakshadweep and North Chennai Thermal Power Station for providing fresh water.

• An Autonomous coring system (ACS) was developed for ground truth validation of gas hydrate occurrence in Indian continental margins and

tested over the sea floor of Krishna Godavari Basin.

- A floating type wave energy device called the Backward Bent Ducted Buoy (BBDB) has been developed and tested successfully in the sea.

MoES Research Vessel Sagar Nidhi deploying ocean buoy

- Various subsystems that are required for mining operations have been developed and sea trials have been performed such as

  ➢ Remotely operable Subsea In-situ Soil tester.
  ➢ An Exploratory Mining System with single module of collector, crusher and hydraulic sub-systems.
  ➢ A Remotely Operable Vehicle (ROV) rated for 6000m water depth for survey and exploration
  ➢ Another ROV rated for shallow water operation, operated at the Priyadarshini Lake, ice shelf in Antarctica and in coral reef in the Andaman Sea.

- Successful demonstration of Open sea cage culture in Andhra Pradesh, Andamans and Tamil Nadu.

- On the request from Government of Puducherry to restore the beach, environmentally friendly shoreline stabilization methodology has been evolved and demonstrated resulting in a gain of 60m wide beach.

- Deployment of OMNI buoys at deep sea for measuring meteorological and oceanographic parameters.

- Development of an indigenous, autonomous ocean ambient noise measuring system for operation in shallow waters off the Indian coasts.

- Autonomous Underwater Profiling Drifter (AUPD) has been successfully tested in the sea and trial production of AUPDs by Indian industry is completed.
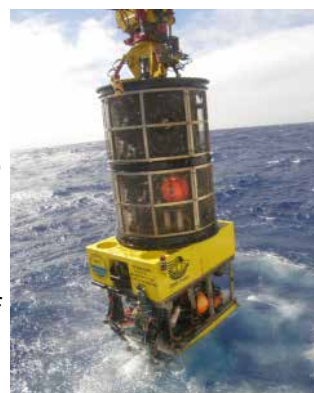
- Indigenized drifter buoys with INSAT communication were deployed in Indian waters.

- Development of *Drishti* systems for measurements of visibility at the airports in collaboration with the National Aerospace Laboratories, CSIR, Bangalore.
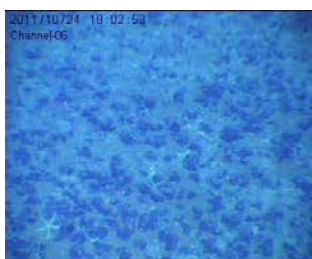
4) Ocean Survey and Exploration

- Survey and mapping of an area of about 1.6 Million Sq Km of Exclusive Economic Zone (EEZ) using the Multi-beam bathymetric techniques and the geoscientific studies.

- Survey and exploration, Environmental impact assessment, technology development for mining and extractive metallurgy for polymetallic nodules (PMN) over the central Indian ocean in accordance with the contract with the International Seabed Authority.

Remotely Operable In-situ Soil Tester (ROSIS)

- First partial submission of India's extended continental Shelf claim submitted to the United Nations.

- Comprehensive marine Geoscientific surveys in parts of the Central Indian Ridge (CIR) and Southwest Indian Ridge (SWIR), thus providing significant clues about potential locations of hydrothermal sulphides in the region.

Manganese nodules in the Central Indian Ocean, photographed by Soil tester

Remotely Operated Submersible - ROSUB6000

5) Polar and Cryosphere Studies

- Exploration of Antarctica, Arctic, Southern Indian Ocean and the Himalayas and scientific studies. Commissioned its third station 'Bharati' - a state-of-the-art research base at Larsemann Hills in March 2012.

- Six expeditions were launched from 2007 to 2016 with National-International collaborations and multi-disciplinary data were generated in the Southern Ocean.

- Research studies on variability of cryosphere using remote sensed data, southern Indian Ocean and past climate and oceanic variability of polar regions.

- Successful Antarctic Ice core programme that led to recovery and study of

several ice cores from coastal Antarctica. Study revealed a substantial warming of 0.6-1.0 ^{0}C per century, Southern Annular Mode and the role of ENSO on Antarctic climate.

- First Expedition to the South Pole carried out in 2010 by a team of multi-institutional scientists

- Established a Research Station in Himalaya with several monitoring systems to support field survey and laboratory studies in Himalaya.

- Discovery of diverse types of carbon compounds that play an active role in the biogeochemical cycling in the Antarctic cryosphere.

Scientific Activities in Antarctica

Expedition to South Pole by Indian Scientists

- Discovery of global teleconnections of Sea ice at Antarctica with linkages on Indian Monsoons and the Indian Ocean Dipole.

- Continuous monitoring of environmental changes over the Antarctica.

- Installation of a Movable Atmospheric Radar for Antarctica (MARA) near the Indian Antarctic Station, Maitri to probe tropospheric and stratospheric structure.

➢ The Indian scientific expeditions to the Arctic commenced in the summer of 2007.
➢ Deployment of IndARC, India's first sub-surface moored observatory in the polar waters of Arctic.
➢ Membership of India in the Arctic Council as an Observer.
➢ Discovery of a Holocene moss species, Pholia nutans, preserved in the lake sediments. The specimen dates back to 10,000 years B.P.

6) Geosciences and Seismology

- Setting up of a National Centre for Seismology (NCS) at New Delhi to provide added thrust to seismological research in the country.

- Strengthening of the Seismic Observational Network: With 23 upgraded

seismic observatories, 21 additional stations, and dedicated networks in NE India and Delhi, NCS now has 84 national observatories with real time data streaming through VSAT connectivity.

Scientific Deep Drilling to understand geological phenonmenon

- VSAT communication facilities to additional 50 seismic stations as well as 30 GPS stations in the country under the ISGN. With the current seismic network, and data centers, an earthquake of M>3 anywhere in the country can be located in 3-5 minutes.

- Seismic microzonation of a few urban centres namely, Guwahati, Bangalore, Sikkim, Delhi and Kolkata to help in disaster mitigation and management, urban development, planning, design and construction, assessment of risk to existing life and property as well as public utilities and services.

- Launching of a major programme on "Scientific deep drilling in the Koyna intraplate seismic zone" to set up deep bore hole observatory for measuring the physical rock properties, understand hydrology and pore pressure at the in-situ conditions to constrain the processes involved in reservoir triggered earthquakes in particular and unveil the sources governing seismicity in stable continental region.

- Setting up of Multi-Parameter Geophysical Observatories at Ghuttu, in NW Himalaya and Imphal in NE region to monitor various geophysical, geochemical and seismological precursory signals.

- Launching of a facility for Geochronology with an objective to generate high-quality geo-chronological data and its characterization.

- For the first time, Deep Sea Drilling in the Laxmi Basin enabled scientists to collect more than 1700m long sediment cores from the Eastern Arabian Sea to understand possible tectono-climatic link.

- First time successful deployments of Ocean Bottom Seismometers in the Indian Ocean Geoidal Low region to understand possible deep seated sources for remarkable geoid anomaly in the Indian Ocean.

7) **Basic research, Infrastructure, human resources development and International Collaboration**

High performance computing system Aditya at IITM Pune

- Establishment of High Performance Computing System with 1.2 Petaflop speed to meet the modelling requirements. This system is now the second fastest computing system in the country.

- Strengthening of training activity of operational Meteorology at the India Meteorological Department.

- Setting up a Centre for Advanced Training in Earth System Science and Climate at IITM Pune.

International Training Centre for Operational Oceanography

- Setting up of an International Training Centre for Operational Oceanography (ITCOocean) at INCOIS, Hyderabad.

- Human Resource Development through establishment of national Facilities, initiation of academic programs and establishment of Chair professorship

- Strengthening of Outreach and Awareness Programme, involvement of social media.

- Successful international cooperation with different countries for collaborative research and human resources development.

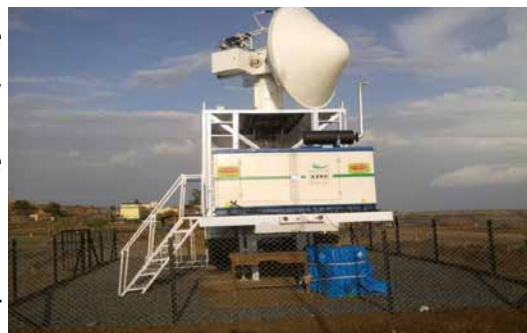- Regional leadership through BIMSTEC, RIMES, Indo-Arc and ITCOocean.

**Vision for
Next 15 years
(up to 2030)**
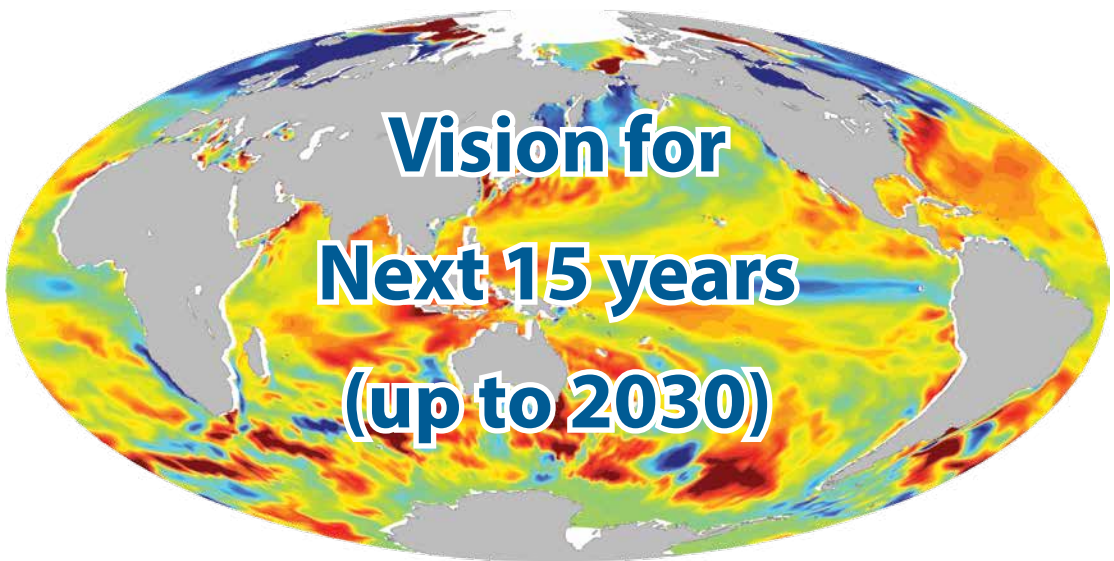
Vision for 15 years (up to 2030)

There is a considerable scope for further accelerating these initiatives to enable the country to become a world leader in providing high quality services, and contribute to economic and societal benefits. We also would like to be a leader in providing all possible services in Earth Sciences to developing countries in Asia and Africa. The vision document has been prepared for next 15 years (up to 2030) keeping in view the social goals set in the Sustainable Development Goals (SDGs).

Weather, Climate and Hydrological Services

1. To set up **atmospheric observational network** at 25x25 km grid and upper air observations at 100x100 km, complimented by Multi-platform Satellite and air-craft based profiler observations, Doppler Radars, Wind profilers, Radiometers, Lightning detectors, and LIDARs.

2. Develop an **Advanced Weather Prediction System**, for block level forecasts, skilful for next 3-5 days and develop advisories for sectors for like Agriculture, Disaster Management, Water resources, Power, Tourism and Pilgrimage, Smart Cities, Renewable Energy Sector and Transport.

3. Develop District level weather and climate service centres for better coordination with the users and government officials for various applications including disaster management.

New atmospheric observations for improvement of weather forecasts

4. Develop an **Advanced Regional Climate Services** Framework to cater to the needs of Agriculture, Water Resources, Alternate Energy Resources and Health on the basis of location specific and user specific knowledge of the climate variability and predictions of climate variables.
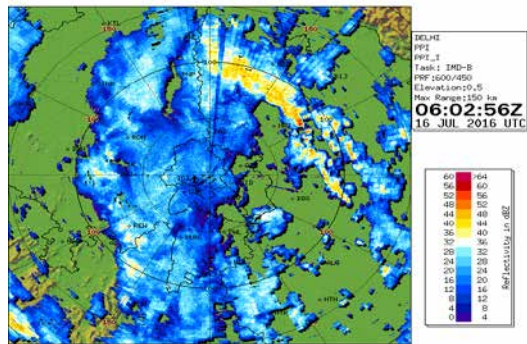
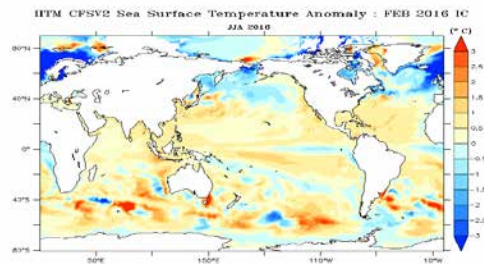Doppler Weather Radars for Now-casting Severe Weather

5. Develop a State-of-the-Art **Support System for Aviation Safety** with the advanced meteorological instruments and advanced forecasting tools for all the civil airports in the Country.

6. Develop a **probabilistic prediction system** based on a coupled model of land-ocean-atmosphere for reliable extended range (up to 15-20 days) and seasonal (for all the four seasons) forecasts of rainfall and temperatures for sub-divisional spatial scale.

Doppler Weather Radars for Now-casting Severe Weather

7. Develop a State-of-the-Art **Earth System Model** to study the climate change aspects and develop future regional climate change scenarios at 25 km resolution and conduct climate impact assessment studies.

8. Monitor the three dimensional variability of **regional hydrological cycle** and assess its expected changes and impacts in the future.

Strengthening of Met Services for Aviation Safety and Prediction of Fog

9. Carry out **process studies of the atmosphere** (aerosols, clouds, land surface processes, boundary layer, and atmospheric chemistry) through setting up of research test beds which are required for substantial improvements in dynamical models.

Climate Prediction and ENSO Advisories

10. Carry out cutting-edge **research studies** on climate variability including monsoons, meteorological droughts, desertification, land use changes using observations and modelling.

11. Monitor and document **regional climate change** by carefully monitoring the components of the climate system and essential climate variables and setting up climate reference stations.

12. Develop Urban **Meteorology Services** with dense Meso network and modelling strategy to cater to the needs of growing cities in the country.

13. Develop a **Weather modification research strategy** to carry out research

studies on artificial rainmaking, hail suppression, fog dispersal and reduction of air pollution.

14. Develop an **Integrated Himalayan Meteorology Programme** for meeting the growing challenge and needs of the Himalayan States.

15. Develop **a Centre of Excellence for addressing the needs of Himalayan and NE States.**

Ocean Services and Marine Geology

1. Sustain and expand the observational system including robotic observing systems (sea gliders, automated profilers) over the Indian Ocean and develop an ocean data management system.

2. Develop an Advanced Ocean Modelling system for predicting the variability of the Indian Ocean (at 1/16th of degree for the Indian Ocean basin and 1/64th degree resolution for the coastal waters around India) for providing best quality Ocean Services, forecasts of the Ocean State, water quality and coastal hazards.

3. Develop Regional Ocean Service Centres to cater to the needs of region specific needs and requirements for ocean services like Potential Fishing Zones (PFZ) and Coastal Ocean State Forecast services for each and every fisherman and stake holder (coastal population, ports and harbours, maritime industry, etc.) in the locality.

New Ocean Observations and Ocean Technology

4. Transform the existing empirically derived PFZ advisories to predictions through finer observations, understanding and modelling of the ecological environment that leads to the formation of PFZ.

5. Develop an Observational and Modelling Strategy specific to Estuarine Systems, Water quality, Ocean Biogeochemistry, Climate change and its impacts on the Oceans including Ocean Acidification, Greenhouse Gases, Marine Ecosystems and Living Resources and Primary Productivity.

6. Develop a Centre of Excellence for Coastal Research.

7.   Conduct cutting edge research for better understanding of ocean and coastal processes, air-sea interaction, Marine pollution using observations, process studies and models.

8.   Carry out studies in the frontier areas of marine geosciences such as Climate-Tectonics interactions and their influence on Earth Surface processes, plate tectonic evolution and development.

9.   Develop beach tourism specific forecast/now cast products to boost the tourism on Indian beaches.

10. Develop Ocean Biogeographic Information System and Census of Marine Life to assess the changes in Marine Biodiversity abundance and distribution from past to future ocean life.

11. Understanding the land-ocean-atmosphere interactions in the Indian Ocean through trace elements and isotopes.

Ocean Survey and Exploration

1.   Conduct Bathymetric, Geophysical and Geological surveys of Exclusive Economic Zone (EEZ) as well as of continental shelf and high seas for exploration of mineral and energy resources.

2.   Conduct investigations related to subduction zone, Geoid anomaly and fragmentation process and movement of the Indian plate, and evolution of Himalaya, Indian Ocean, etc.

3.   Exploration of deep sea non-living resources including polymetallic nodules, polymetallic sulphides and cobalt enriched crust.

4.   Exploration and delineation of marine biodiversity hotspots with ecological and economic significance in the areas beyond National jurisdiction.

Atmospheric and Ocean Technology

1.   Support the initiatives of **Blue Economy** by innovating, developing and demonstrating world class technologies for exploration and **harnessing ocean resources- Energy, Water and Minerals**.

2.   Develop and deploy technologies for exploring and sustainable utilisation of marine resources including off-shore cage cultures.

3.   Develop the state-of-the-art sensors, electronics, communication and acoustic systems for ocean observation, exploration and deep sea operations

4.   Develop capabilities in design of safe and economic offshore structures/systems and development of offshore numerical tank.

Exploration of Ocean Green Energy

5.   To develop green and blue infrastructure for sustainable coastal development and protection

6.   Develop a **Centre of Excellence for Deep Sea Research**

7.   Promote the "Make in India" initiative by nurturing Indian industry in manufacturing atmospheric, oceanic and geological instruments.

Polar Sciences and Cryosphere

1.   Explore the Polar Regions of Antarctica and the Arctic as well as the Himalayan glaciers for monitoring and predicting the variability of the fragile global cryosphere system.

2.   Conduct cutting-edge research (through observations and modelling) to better understand the geology and climatic history of Antarctica and the Arctic,

Monitoring Himalayan Glaciers

variability of the polar atmosphere and southern Ocean, environment and ecosystem dynamics, and cryosphere-climate interactions.

3.   Explore and determine the teleconnection between the polar regions and the tropics for improving weather and climate predictions

Geosciences and Seismology

1.   To develop 3-D model of the lithosphere to understand the geodynamical processes

2.   Conduct research on understanding the crustal structure, deformation, and rupture, mountain dynamics, critical zone studies, paleo magnetism, and earthquake precursors over high risk zones of the country.

3.   Conduct scientific experiments by scientific deep drilling to understand geological phenomena related to probe interior of earth and promote borehole geophysical research

4.   Launching studies on landslide generation processes

Multi-hazard Early Warning Systems for Disaster Risk Management

1.   Develop a Decision Support Systems (DSS) based on predictions of a) Tropical cyclones and associated damages over the Indian Seas and **7 days in advance** with the 24/48/72 hour Land-fall errors of 30/60/100 km respectively, b) Severe

weather (heavy rainfall, urban floods, Fog, Air pollution emergencies, Heat and Cold waves) at district/block level **3-5-days in advance** and c) location specific nowcasts of thunderstorms, lightning, wind storms and flash floods (3-12 hours in advance).

Forewarning Landslides

2. Develop a State-of-the-Art **Hydrological Information System and Flood Warning** Support for all the Major River Basins of the Country.

3. Augmentation and improvements in Tsunami and Storm Surge Early warning Decision Support Systems.

Ensemble Probabilistic Forecasts for Severe Weather events

4. Develop a **Coastal Mission** for an integrated coastal multi-hazard warning and dissemination system for addressing Hydro-meteorological (Storm Surge, Sea-level Rise, High Waves), Geological (Tsunami and coastal erosion) and Ecosystem related (Coral Bleaching and Harmful Algal Blooms) hazards and related services.

5. Develop a Decision Support Systems (DSS) for Earthquakes by augmenting the seismological network optimally over the country and neighborhood so that

Hydrological Information and Flood Warning Systems

Earthquakes of magnitude 2.5 and above are detected with improved accuracy of location and dissemination of the Earthquake details within 5 minutes of occurrence.

6. Development of micro-zonation maps for all urban cities in the seismic zones of the country.

Basic research, Infrastructure, human resources development and International Collaboration

1. Conduct cutting-edge science on Physics and Predictability of the Earth System processes and variability in collaboration with the national and international academic and research institutions.

2. Develop required infrastructure with High performance computers, aircrafts and research ships including polar research vessel and a Sea-front facility.

3. Develop skilled and trained manpower in Earth Sciences with the support of academic institutions in the country and abroad.

4. Develop useful collaborations with international organizations for mutual transfer of advanced knowledge in science and technology in Earth Sciences and to provide services to developing countries.

5. Set up satellite centres of MoES Institutes, specifically state of the art sea front facility at Nellore, Andhra Pradesh

6. Set up Earth System Enterprise for commercialising the technologies and services generated by the MoES Institutes as part of Make in India initiative

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